

## CHAPTER 7: PREVENTION PROGRAM (PROGRAM 3)

Many of you will need to do little that is new to comply with the Program 3 prevention program, because you already have the OSHA PSM program in place. Whether you're building on the PSM standard or creating a new program, keep these things in mind.

- g EPA and OSHA have different legal authority — EPA for offsite consequences, OSHA for on-site consequences. If you are already complying with the PSM standard, your process hazard analysis (PHA) team may have to assess new hazards that could affect the public or the environment offsite. Protection measures that are suitable for workers (e.g., venting releases to the outdoors) may be the very kind of thing that could expose the public to toxic substances.
- g Integrate the elements of your prevention program. You must ensure that a change in any single element of your program leads to a review of other elements to identify any effect caused by the change.
- g Most importantly, make accident prevention an institution at your site. Like the entire risk management program, a prevention program is more than a collection of written documents. It is a way to make safe operations and accident prevention the way you do business everyday.

### 7.1 PROGRAM 3 PREVENTION PROGRAM AND OSHA PSM

The Program 3 prevention program includes the requirements of the OSHA PSM standard. Whenever we could, EPA used OSHA's language verbatim. However, there were a few terms that EPA had to change to reflect the differences between its authority and OSHA's. For example, OSHA regulates to protect workers; EPA's responsibility is to protect public health and safety and the environment. Therefore, an "owner or operator" subject to EPA's rule must investigate catastrophic releases "that present(s) (an) imminent and substantial endangerment to public health and the environment," but an OSHA "employer" would focus its concerns on the workplace. To clarify these distinctions, we deleted specific references to workplace impacts and "safety and health" contained in OSHA's PSM standards. We also used different schedule dates and references where appropriate. Exhibit 7-1 compares terms in EPA's rule with their counterparts in the OSHA PSM standard.

### EXHIBIT 7-1 COMPARABLE EPA AND OSHA TERMS

OSHA TERM	EPA TERM
Highly hazardous substance	Regulated substance
Employer	Owner or operator
Facility	Stationary source
Standard	Rule or part

There are twelve elements in the Program 3 prevention program. Each element corresponds with a section of subpart D of part 68. Exhibit 7-2 sets out each of the twelve elements, the corresponding section numbers, and OSHA references. Two OSHA elements are not included. Emergency response is dealt with separately in part 68; the OSHA trade secrets requirement (provision of trade secret information to employees) is beyond EPA's statutory authority.

### EXHIBIT 7-2 SUMMARY OF PROGRAM 3 PREVENTION PROGRAM (40 CFR PART 68, SUBPART D)

SECTION	TITLE	OSHA PSM REFERENCE
§ 68.65	Process Safety Information	PSM standard § 1910.119(d).
§ 68.67	Process Hazard Analysis (PHA)	PSM standard § 1910.119(e).
§ 68.69	Operating Procedures	PSM standard § 1910.119(f).
§ 68.71	Training	PSM standard § 1910.119(g).
§ 68.73	Mechanical Integrity	PSM standard § 1910.119(j).
§ 68.75	Management of Change	PSM standard § 1910.119(l).
§ 68.77	Pre-Startup Review	PSM standard § 1910.119(i).
§ 68.79	Compliance Audits	PSM standard § 1910.119(o).
§ 68.81	Incident Investigation	PSM standard § 1910.119(m).
§ 68.83	Employee Participation	PSM standard § 1910.119(c).
§ 68.85	Hot Work Permit	PSM standard § 1910.119(k).
§ 68.87	Contractors	PSM standard § 1910.119(h).

OSHA provided guidance on PSM in non-mandatory appendix C to the standard. OSHA has reprinted this appendix as PSM Guidelines for Compliance (OSHA 3133). The OSHA guidance is reproduced, reordered to track part 68, in Appendix

D. The remainder of this chapter briefly outlines the major requirements and provides a discussion of any differences between EPA and OSHA. In some cases, further guidance specific to WWTPs is provided. For more detailed guidance, you should refer to the OSHA guidance in Appendix D.

### Qs & As

#### IMPLEMENTATION AND PROCESS

**Q.** My process is a series of storage and process vessels, connected by piping, containing several regulated substances, with a few co-located tanks of other substances. Do I have to implement one prevention program to cover all aspects of the process even if different operators, different process chemistry, and different hazards are involved in various parts of the process?

**A.** You should implement the program in the way that makes sense to you. For a complex process such as yours, you may need to divide the process into sections (e.g., production units for particular products, storage units) for the PHA and compliance audits, to keep the analyses manageable. Operating and maintenance procedures (and the training in these procedures) should be developed for operating units; combining procedures for different types of units into a single document may make them harder to use; training operators in procedures they do not need would waste time and perhaps confuse operators. You may want to collect and store process safety information by individual units to make it easier to use. Other parts of the program (contractors, employee participation, procedures for pre-startup, management of change, and hot work) are likely to be common to all parts of the process.

**Q.** I have a tank with more than 10,000 pounds of propane. I use the propane to heat the offices. The propane is not subject to PSM or the risk management program rule. The tank, however, is close to equipment that has chlorine above the applicable threshold and is subject to OSHA PSM and Program 3. Is the tank considered part of the chlorine process?

**A.** If a fire or explosion in the propane tank could cause a release of chlorine or other regulated substances or interfere with mitigation of such a release, the tank is considered part of the process. When you do your PHA for the process, you must evaluate how the propane tank could cause a release of chlorine and determine what steps may be needed to prevent such releases.

## 7.2 PROCESS SAFETY INFORMATION (§68.65)

Exhibit 7-3 briefly summarizes the process safety information requirements.

MSDSs will provide information on chemicals, except for inadvertent mixing with other chemicals. Information on the hazardous effects of inadvertent mixing can come from the PHA checklist (see the following section on process hazard analyses.) MSDSs are available from your supplier of chemicals. But, because methane (CH<sub>4</sub>) is generated in your plant, you will have to find an MSDS for methane elsewhere. A local utility supplying natural gas may have one. You may, however, have to add the potential for inclusion of carbon dioxide, hydrogen sulfide, and water in the methane

stream. If these are present, then corrosivity information about that stream will be needed. You may wish to ask for assistance from a process engineer.

The information listed in the second column of Exhibit 7-3 is needed for that part of your plant where the regulated substances are used. It should be available from the engineering firm that designed the plant. If not, you will have to develop it to meet this rule. The last item, consequences of deviation, means that you need to know what will happen if the process (including any safety controls) does not work the way it was designed to. If you do not have this information, or it cannot be obtained from the engineering firm that designed the plant, it can be developed during the process hazard analysis.

### EXHIBIT 7-3 PROCESS SAFETY INFORMATION REQUIREMENTS

<b><u>For chemicals, you must complete information on:</u></b>	<b><u>For process technology, you must provide:</u></b>	<b><u>For equipment in the process, you must include information on:</u></b>
<ul style="list-style-type: none"> <li>U Toxicity</li> <li>U Permissible exposure limits</li> <li>U Physical data</li> <li>U Reactivity</li> <li>U Corrosivity</li> <li>U Thermal &amp; chemical stability</li> <li>U Hazardous effects of inadvertent mixing of materials that could foreseeably occur</li> </ul>	<ul style="list-style-type: none"> <li>U A block flow diagram or simplified process flow diagram</li> <li>U Information on process chemistry</li> <li>U Maximum intended inventory of the EPA-regulated chemical</li> <li>U Safe upper &amp; lower limits for such items as temperature, pressure, flows, or composition</li> <li>U An evaluation of the consequences of deviation</li> </ul>	<ul style="list-style-type: none"> <li>U Materials of construction</li> <li>U Piping &amp; instrument diagrams (P&amp;IDs)</li> <li>U Electrical classification</li> <li>U Relief system design &amp; design basis</li> <li>U Ventilation system design</li> <li>U Design codes &amp; standards employed</li> <li>U Safety systems</li> <li>U Material and energy balances for processes built after June 21, 1999</li> </ul>

You must maintain equipment information for your plant. Such information is ordinarily supplied with the construction of the plant, and with major replacements and revisions to the plant. Generally, equipment information is found in operations and maintenance (O&M) manuals or equipment submittals. The rule only requires that you have information for that part of your plant that handles, or could cause a release of, the regulated substances you have.

#### WHERE TO GO FOR MORE INFORMATION

**Diagrams.** You may find it useful to consult Appendix B of OSHA's PSM final rule, computer software programs that do P&IDs, or other diagrams.

**Guidance and Reports.** Various engineering societies issue technical reports relating to process design. Other sources you may find useful include:

- g *Guidelines for Process Safety Documentation*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g *Emergency Relief System Design Using DIERS Technology*, American Institute of Chemical Engineers, 1992.
- g *Emergency Relief Systems for Runaway Chemical Reactions and Storage Vessels: A Summary of Multiphase Flow Methods*, American Institute of Chemical Engineers, 1986.
- g *Guidelines for Pressure Relief and Emergency Handling Systems*, Center for Chemical Process Safety of the American Institute of Chemical Engineers, 1998.
- g *Loss Prevention in the Process Industries*, Volumes I, II, and III, Frank P. Lees, Butterworths: London 1996.

The Chlorine Institute publishes a number of documents on chlorine handling including:

- g Chlorine Vaporizing Systems, Pamphlet # 9.
- g Cylinder and Ton Container Procedures for Chlorine Packaging, Pamphlet # 17.
- g Water and Wastewater Operators Chlorine Handbook, Pamphlet # 155.

The Compressed Gas Association publishes:

- g *Sulfur Dioxide* on properties, storage, handling, and use of sulfur dioxide (Order # G-3).
- g ANSI K61.1 on the storage and handling of anhydrous ammonia (Order # G 2.1).
- g *Anhydrous Ammonia* on properties, storage, handling, and use of anhydrous ammonia (Order # G-2).

NFPA-820 (Standard for Fire Protection in Wastewater Treatment and Collection Facilities) provides guidance on design issues.

**MSDSs.** MSDSs are available from a number of websites. The University of Vermont provides access to three university-maintained MSDS collections on its website: <http://www.hazard.com>. The on-line databases usually have multiple copies of MSDSs for each substance and can help you find an MSDS that is well organized and easy to read. EPA has not verified the accuracy or completeness of MSDSs on any of these sites nor does it endorse any particular version of an MSDS. You should review any MSDS you use to ensure that it meets the requirements of the hazard communication standard (29 CFR 1910.1200).

**QS & AS**  
**PROCESS SAFETY INFORMATION**

**Q.** What does “materials of construction” apply to and how do I find this information?

**A.** You must document the materials of construction for all process equipment in a covered process. For example, you need to know the materials of construction for process vessels, storage vessels, piping, hoses, valves, and flanges. Equipment specifications should provide this information.

**Q.** What does “electrical classification” mean?

**A.** Equipment and wiring for locations where fire and explosion hazards may exist must meet requirements based on the hazards. Each room, section, or area must be considered separately. Equipment should be marked to show Class, Group, and operating temperature or temperature range. You must determine the appropriate classification for each area and ensure that the equipment used is suitable for that classification. The equipment covered includes transformers, capacitors, motors, instruments, relays, wiring, switches, fuses, generators, lighting, alarms, remote controls, communication, and grounding. Electrical classification will be included in equipment specifications.

**Q.** What does “relief system design basis” mean?

**A.** Relief systems include, but are not limited to, relief valves, relief headers, relief drums, and rupture disks. Design basis means documenting how the loads and sizes of the relief system, as well as inlet and outlet sizes, were determined. This includes a description of overpressure scenarios considered, the scenario that creates the largest load to be relieved, the assumptions used, and if the device meets a certain code. Relief devices on pressure vessels must conform to ASME codes. Industry codes (e.g., API RP 520) also provide guidance on scenarios that should be considered and on equations for sizing of devices. Scenarios you may need to consider include fire, blocked flow, control valve failure, overheating, power outage, tube rupture, and cooling water failure. For two-phase flow, you should review AIChE publications from the Design Institute for Emergency Relief Systems (DIERS).

**Q.** What do I have to do for material and energy balances?

**A.** For new processes, you must document both material and energy inputs and outputs of a process. For example, you would document the quantity of a regulated substance added to the process, the quantity consumed during the process, and the quantity that remains in the output. This requirement will not generally apply to storage processes.

### **7.3 PROCESS HAZARD ANALYSIS (§68.67)**

Exhibit 7-4 provides a summary of the requirements for process hazard analyses (PHAs).

### EXHIBIT 7-4 PROCESS HAZARD ANALYSIS REQUIREMENTS

<u>The PHA must cover::</u>	<u>Techniques must be one or more of:</u>	<u>Other requirements:</u>
<ul style="list-style-type: none"> <li>UHazards of the process</li> <li>UIdentification of previous, potentially catastrophic incidents</li> <li>UEngineering and administrative controls applicable to the hazards</li> <li>UConsequence of failure of controls</li> <li>USiting</li> <li>UHuman factors</li> <li>UQualitative evaluation of health and safety impacts of control failure</li> </ul>	<ul style="list-style-type: none"> <li>UWhat If</li> <li>UChecklist</li> <li>UWhat If/Checklist</li> <li>UHazard and Operability Study (HAZOP)</li> <li>UFailure Mode and Effects Analysis (FMEA)</li> <li>UFault Tree Analysis</li> <li>UAppropriate equivalent methodology</li> </ul>	<ul style="list-style-type: none"> <li>UAnalysis must be done by a team, one member of which has experience in the process, one member of which is knowledgeable in the PHA technique</li> <li>UA system must be developed for addressing the team's recommendations and documenting resolution and corrective actions taken</li> <li>UThe PHA must be updated at least once every five years</li> <li>UPHAs and documentation of actions must be kept for the life of the process</li> </ul>

#### EPA/OSHA DIFFERENCES

You can use a PHA conducted under the OSHA PSM standard as your initial process hazard analysis. All OSHA PHAs must have been completed by May 1997. Therefore, the only "new" PHAs will be for non-OSHA Program 3 processes. If the process is subject to OSHA PSM, you can update and revalidate your PHA on OSHA's schedule.

**Offsite impacts.** You should consider offsite impacts when you conduct a PHA under EPA's rule (except for an initial PHA where are using the PHA conducted for OSHA PSM). If you are in the Program 3 prevention program because you must comply with the PSM standard, you may not have fully considered offsite consequence because the focus of PSM is worker protection. Practically speaking, however, there should be few instances where the scenarios considered for OSHA fail to address offsite impacts. A well-done PHA should identify all failure scenarios that could lead to significant exposure of workers, the public, or the environment. The only issue that may require further consideration for part 68 processes is whether any protection measures that were adequate for worker safety are inadequate for public and environmental safety.

Consider two circumstances — one where OSHA's PSM standard and EPA's risk management program rule lead to the same result, and another where protecting workers could mean endangering the public and the environment. For flammables, any scenario that could affect the public almost certainly would have the potential to

affect workers; measures taken to protect your employees likely will protect the public and the environment. For toxics under PSM, however, you may plan to address a loss of containment by venting toxic vapors to the outside air. In each circumstance, a PHA should define how the loss of containment could occur. However, for EPA, the PHA team should reassess venting as an appropriate mitigation measure.

**Updating and revalidating your PHA.** For EPA, you must complete the initial PHA for each Program 3 process not later than June 21, 1999, and update it at least once every five years. You may complete an initial PHA before that date. You may use an OSHA PHA as your initial PHA, and update and revalidate it every five years on the OSHA schedule. A PHA completed after August 19, 1996 (the effective date of part 68) should consider offsite impacts.

## **METHODS**

Unless your WWTP is uncommonly complex, the checklist method is likely to be sufficient to meet the need in smaller plants. Operators might find it practical to add what-if questions to supplement the checklist, or use the what-if/checklist method. See the guidance provided in Program 2, section 6-3 and Appendix A to Chapter 6, for examples of checklists and what-if questions. Guidance on how to use these methods, or HAZOPs, is included in that chapter.

If the chlorine, sulfur dioxide, or ammonia receiving and storage facilities are designed to receive tank truck or rail car quantities, then the Hazard and Operability (HAZOP) method is likely to be best. If you do not have anyone on staff who has taken part in a HAZOP or taken HAZOP training, you may want to engage a skilled study leader.

## **REJECTING TEAM RECOMMENDATIONS**

You may not always agree with your PHA team's recommendations and may wish to reject a recommendation. OSHA's compliance directive CPL 2-2.45A-revised states that you may decline a team recommendation if you can document one of the following: (1) the analysis upon which the recommendation is based contains factual errors; (2) the recommendation is not necessary to protect the health of employees or contractors; (3) an alternative measure would provide a sufficient level of protection; or (4) the recommendation is infeasible. For part 68, you should also consider whether recommendations are not necessary to protect public health and the environment.

## **UPDATING YOUR PHA**

You should update or revalidate your PHA whenever there is a new hazard or risk created by changes to your process. Such changes might include introducing a new process, process equipment, or regulated substance; altering process chemistry that results in any change to safe operating limits; or other alteration that introduces a new hazard. You might, for example, introduce a new hazard if you installed a gas



pipeline next to a storage tank containing a regulated substance. Other candidates could be making changes in process constituents that increase the possibility of runaway reactions or polymerization. EPA recommends that you consider revalidating your PHA whenever adjoining processes create a hazard. Remember that you have a general duty to prevent accidents and ensure safety at your source, which may require you to take steps beyond those specified in the risk management program rule.

### **Qs & As**

#### **OFFSITE CONSEQUENCES**

**Q.** What does EPA mean by "consider offsite consequences"? Do we have to do an environmental impact assessment (EIA)?

**A.** EPA does not expect you to do an EIA. Potential consequences to the public and the environment are already analyzed in the offsite consequence analysis. In the PHA, EPA only expects you to identify any failure scenarios that could lead to public exposures and to examine whether your strategies are adequate to reduce the risk of such exposures.

**Q.** If I need to revise a PHA to consider offsite consequences, when do I have to do that?

**A.** In general, for a PHA completed to meet the requirements of OSHA PSM, you should revise the PHA to consider offsite consequences when you update that PHA. Any PHA for a covered process completed or updated for OSHA PSM after August 19, 1996, when part 68 was effective, should examine offsite consequences. For example, if you completed an initial PHA for OSHA PSM in May 1993, OSHA requires that you update that PHA by May 1998. In that update, you should consider offsite consequences. If you complete your initial PHA for OSHA in May 1995, you must update it by May 2000; PHAs conducted for part 68 must include consideration of offsite consequences at that time.

### **WHERE TO GO FOR MORE INFORMATION**

Appendix 7-A of this chapter provides a summary of each of the techniques, a description of the types of processes for which they may be appropriate, and estimates about the time and staff required for each.

Part 68 and OSHA PSM require that whichever technique or techniques you use, you must have at least one person on the PHA team who is trained in the use of the technique. Training on such techniques is available from a number of professional organizations as well as private companies. You may have staff members who are capable of providing this training as well. Many trade associations publish detailed guidance on methods for conducting a process hazard analysis. You might find the following documents useful.

- g *Guidelines for Hazard Evaluation Procedures*, 2nd Ed. with Worked examples, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1992.
- g *Evaluating Process Safety in the Chemical Industry*, Chemical Manufacturers Association.
- g *Loss Prevention in the Process Industries, Volumes I, II, and III*, Frank P. Lees, Butterworths: London 1996.
- g *Management of Process Hazards* (RP 750), American Petroleum Institute.
- g *Risk-Based Decision Making* (Publication 16288), American Petroleum Institute.

## 7.4 OPERATING PROCEDURES (§68.69)

Exhibit 7-5 summarizes what your operating procedures must address. Operating procedures must be readily accessible to workers who operate or maintain the process. You must review operating procedures as often as necessary to assure that they reflect current practices and any changes to the process or facility. You must certify annually that the operating procedures are current and accurate.

In a WWTP, it will be especially important to detail, very specifically, the procedures and safeguards for connecting and disconnecting cylinders, tank trucks or rail cars of regulated substances. These procedures should also detail the required precautions, e.g., having an emergency respirator readily available. Also, assuring that emergency equipment is functional and readily available should be part of the instructions. For example, an inspection of the air tank on self-contained breathing apparatus prior to making or breaking connections should be considered.

In WWTPs, it is likely that regular operating procedures will include startup, normal operations, and normal shutdown. Provision for emergency shutdown and startup following a turnaround or emergency shutdown need to be included only to the extent that they differ from your regular procedures. These procedures should also detail what to do in the event of an emergency. In particular, they must include the shutdown actions operators should take, without reference to supervisors, to avoid more serious consequences and the conditions requiring them.

The *operating limits* section should detail what would happen if the actual operating parameters (pressure, flow, temperature) were higher or lower than intended. Then the procedures should tell operators what to do to correct them.

The *safety system* section should explain all about your safety systems. These are alarms, shutdown devices, relief systems, remote telephone alerting systems, and the like. The procedures should show:

- g What the system or device is.

- g What it is supposed to do.
- g How it works.
- g How to operate it, if operators must initiate action.

### EXHIBIT 7-5 OPERATING PROCEDURES REQUIREMENTS

<u>Steps for each operating phase</u>	<u>Operating limits</u>	<u>Safety &amp; health considerations</u>	<u>Safety systems &amp; their functions</u>
<ul style="list-style-type: none"> <li>U Initial startup</li> <li>U Normal operations</li> <li>U Temporary operations</li> <li>U Emergency shutdown</li> <li>U Emergency operations</li> <li>U Normal shutdown</li> <li>U Startup following a turnaround or emergency shutdown</li> <li>U Lockout/tagout</li> <li>U Confined space entry</li> <li>U Opening process equipment or piping</li> <li>U Entrance into the facility</li> </ul>	<ul style="list-style-type: none"> <li>U Consequences of deviations</li> <li>U Steps to avoid, correct deviations</li> </ul>	<ul style="list-style-type: none"> <li>U Chemical properties &amp; hazards</li> <li>U Precautions for preventing chemical exposure</li> <li>U Control measures for exposure</li> <li>U QC for raw materials and chemical inventory</li> <li>U Special or unique hazards</li> </ul>	<ul style="list-style-type: none"> <li>U Address whatever is applicable</li> </ul>

Operating procedures, especially for plants that run unattended overnight or on weekends, should include provisions to prevent vandalism or sabotage by use of locks, fences, police patrol, or other secure means.

#### WHERE TO GO FOR MORE INFORMATION

Chapter 6 of this document provides descriptions of each operating phase and when these phases may not apply to certain operations.

The Chlorine Institute (<http://www.cl2.com>) publishes information on safe use and handling of chlorine. Its *Water and Wastewater Operators Chlorine Handbook* (Pamphlet # 155) provides general training and procedures.

The Water Environment Federation (601 Wythe Street, Alexandria, VA 22134, (703) 684-2470) provides general procedures as part of its training programs for wastewater treatment.

Although the reports below target the chemical industry, you may find useful information in them:

- g *Guidelines for Process Safety Fundamentals for General Plant Operations*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g *Guidelines for Safe Process Operations and Maintenance*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g *Guidelines for Writing Effective Operating and Maintenance Procedures*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1996.

## 7.5 TRAINING (\$68.71)

You are required to train new operators on the operating procedures and cover health and safety hazards, emergency operations, and safe work practices applicable to the employee's tasks. For workers involved in operating the process before June 21, 1999, you may certify in writing that they are competent to operate the process safely, in accordance with the operating procedures. At least every three years you must provide refresher training (you must consult with employees involved in operating the process to determine the appropriate frequency). Finally, you are required to determine that each operator has received and understood the training and keep a record for each employee with the date of the training and the method used to verify that the employee understood the training.

For WWTPs, training should cover the activities that could lead to releases of the toxic gases and flammables that are used in WWTPs. These activities should be identified in the process hazard analysis and bear particular attention:

- g Connecting, and disconnecting, cylinders of Chlorine and Sulfur Dioxide. Training should cover inspection of the fittings and tubing to assure that they are in good condition and inspection (and discard if necessary) of tools used for the job. Training should also include identification of vapor and liquid connections on the cylinders and identification of the operating conditions that will show that the connections are hooked up in reverse.
- g Material handling of cylinders. Training should cover inspection of material handling equipment, including hoists, cylinder carriers and hooks, and cylinder chocks. Also, inspection for and removal of combustibles or flammables in storage areas should be a part of training.

### WHERE TO GO FOR MORE INFORMATION

The Water Environment Federation provides several training programs including the following:

- g *Basic Course for Wastewater Treatment Plant Operators*, Instructor Set Order No. E0100GB, Student Workbook Order No. E0110GB.

- g *Intermediate Course for Wastewater Treatment Plant Operators*, Instructor Set Order No. E0295GB, Student Workbook Order No. E0296GB.
- g *Chlorination Skill Training Course*, Order No. E0312GB. Self Instruction Course.

In addition, the following may be useful.

- g *Guidelines for Process Safety Fundamentals for General Plant Operations*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g *Guidelines for Technical Planning for On-Site Emergencies*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g *Federally Mandated Training and Information (Publication 12000)*, American Petroleum Institute.

## 7.6 MECHANICAL INTEGRITY (\$68.73)

You must have a mechanical integrity program for pressure vessels and storage tanks, piping systems, relief and vent systems and devices, emergency shutdown systems, controls, and pumps. Exhibit 7-6 briefly summarizes the other requirements for your mechanical integrity program. The mechanic integrity requirement is similar to the maintenance requirement under Program 2, but covers additional areas, such as quality assurance.

For most of the equipment in a WWTP, the manufacturer will have supplied maintenance instructions. These can be used to fulfill the requirements for maintenance procedures. Where such instructions are not available, you will need to develop them. In addition to the major pieces of equipment, you will need to develop inspection procedures that consider both repair or replacement requirements for the following items:

- g Fittings
- g Tubing
- g Pressure relief devices
- g Gauges, pressure switches, and other instrumentation
- g Rotameters
- g Pressure regulators, and pressure gauges
- g Leak detectors
- g Eductors, vacuum mixers, or other devices used to mix chlorine, sulfur dioxide, and other regulated substances into waste water streams
- g Material handling equipment
- g Tools
- g All other equipment used to handle, transfer, or use the regulated substances.

## EXHIBIT 7-6 MECHANICAL INTEGRITY CHART

Written procedures	Training	Inspection & testing	Equipment deficiencies	Quality assurance
<p>U Establish &amp; implement written procedures to maintain the integrity of process equipment.</p>	<p>U Train process maintenance employees in an overview of the process and its hazards.</p> <p>U Make sure this training covers the procedures applicable to safe job performance.</p>	<p>U Inspect &amp; test process equipment.</p> <p>U Use recognized and generally accepted good engineering practices.</p> <p>U Follow a schedule that matches the manufacturer's recommendations or more frequently if prior operating experience indicates is necessary.</p> <p>U Document each inspection &amp; test with: Date, inspector name, equipment identifier, test or inspection performed, results.</p>	<p>U Correct equipment deficiencies before further use of process equipment or whenever necessary to ensure safety.</p>	<p>U Establish a QA program for new construction &amp; equipment, newly installed equipment, maintenance materials, and spare parts &amp; equipment.</p>

Where there is the possibility of corrosion, these inspections are especially important. The regulated substances used are normally not corrosive, when they are dry. However, all of them can become highly corrosive if the equipment using them is wet. Attention to this aspect can be vital.

In larger plants, where there are storage tanks for chlorine, sulfur dioxide or ammonia, the tanks and associated piping should be inspected regularly. Suppliers are likely to be able to provide recommendations for this inspection and preventive maintenance.

You may need to cover a number of the maintenance procedures. The value in these procedures comes from the use of permits as a communication device. They are

intended to communicate the hazards, and needed precautions, to the workers performing work under the permits. Also, the provision of the permit to operators will inform them of the nature of the work in progress, so that they can govern their activity so as not to interfere with or provide additional hazard to the job in progress.

The maintenance procedures you need are the following:

- g** Confined space entry. For guidance see the OSHA standard, 29 CFR 1910.146
- g** Lockout-tagout. For guidance, see the OSHA standard 29 CFR 1910.146.
- g** Pipeline breaking. Operators should prepare their own procedure that:
  - f** Provide a means to communicate the hazards that might be presented to those who will encounter them.
  - f** Provide a list the precautions needed to safely control these hazards.
  - f** Provide a means to communicate these precautions, and insure that they are understood by those who must take the precautions.
  - f** Provide a requirement that these precautions are effectively taken and remain in place until the work is complete.
- g** Control of entry into hazardous areas. Operators should provide a procedure that controls the access of individuals to places where regulated materials are stored, handled or used. There are three objectives to this control:
  - f** Limit potential exposure to hazardous materials to only the essential requirements.
  - f** Insure that only properly trained or informed persons have access to hazardous material locations.
  - f** Ensure that the hazardous areas are secure.

Operators are expected to provide spare parts store where needed. Spare parts kept on hand, are an important part of Mechanical Integrity. There is some plant equipment, like cylinder connection tubing and connecting devices, that must not be used when they are worn. Prompt replacement is a valuable preventive action. The operator must assure that critical parts are readily available. As part of the Quality Assurance (see column 5 of Exhibit 7-6) needs, operators are expected to assure that these are the right spare parts. Substitution of parts of the wrong specification can lead to a catastrophic release of these hazardous materials.

## WHERE TO GO FOR MORE INFORMATION

**Guidance and Reports.** The documents listed under Process Safety Information may be useful for maintenance procedures as well. In addition, the Chlorine Institute publishes pamphlets on chlorine system maintenance, including the following:

- g** *Maintenance Instructions for Chlorine Institute Standard Safety Valves, Type 1-1/2 JQ (# 39).*
- g** *Maintenance Instructions for Chlorine Institute Standard Angle Valve (#40).*
- g** *Maintenance Instructions for Chlorine Institute Standard Safety Valve, Type 4JQ (#41).*
- g** *Maintenance Instructions for Chlorine Institute Standard Excess Flow Valves (#42).*

Other sources of guidance and reports you may find useful include:

- g** *Guidelines for Process Equipment Reliability Data with Data Tables*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1989.
- g** *Guidelines for Process Safety Documentation*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1995.
- g** *Pressure Vessel Inspection Code: Maintenance Inspection, Rating, Repair, and Alteration (API 510)*, American Petroleum Institute.
- g** *Tank Inspection, Repair, Alteration, and Reconstruction (Std 653)*, American Petroleum Institute.

## 7.7 MANAGEMENT OF CHANGE (§68.75)

Exhibits 7-7 briefly summarizes EPA's MOC requirements.



## EXHIBIT 7-7 MANAGEMENT OF CHANGE REQUIREMENTS

<b>MOC procedures must address:</b>	<b>Employees affected by the change must:</b>	<b>Update process safety information if:</b>	<b>Update operating procedures if:</b>
<b>U</b> Technical basis for the change  <b>U</b> Impact on safety and health  <b>U</b> Modifications to operating procedures  <b>U</b> Necessary time period for the change  <b>U</b> Authorization requirements for proposed change	<b>U</b> Be informed of the change before startup  <b>U</b> Trained in the change before startup	<b>U</b> A change covered by MOC procedures results in a change in any PSI required under EPA's rule (see § 67.65)	<b>U</b> A change covered by MOC procedures results in a change in any operating procedure required under EPA's rule (see § 67.69)

The purpose of this element of the RMP rule, and the next element, pre-startup review, is to make sure that, if you make a change to your covered process or your facility in a way that affects a covered process, that you do so safely.

The management of change provision will apply when you make a change that can affect a regulated substance, (for example, by adding chlorine directly to the contactor instead of dissolving it in water first). Or it will apply if you add a regulated substance (for example, by adding a new digester that runs your total mass of digester gas over the 10,000 pound threshold). Or you may change tubing from steel to plastic. Or you may build a new chemical storage building that houses Cl<sub>2</sub> and SO<sub>2</sub> in the same place, where you had separate buildings previously.

Any change that affects the regulated substances, whether in storage, use, or processing, is subject to Management of Change. It does **not** apply to repairs or maintenance or in-kind replacements. Also, it does not apply when you make a change in processing conditions that are within the normal bounds of operation, like a change in Cl<sub>2</sub> addition rate.

**Method of review.** The first column of Exhibit 7-7 calls for understanding the impact of the change on safety and health. This usually means that some study is needed. If the change is a major one (e.g., a new chlorine storage building for bulk

chlorine), you might choose to run a full-blown Hazard and Operability study (HAZOP). Your engineering firm, or engineer, is likely to organize it. For a small change (e.g., a not-in-kind replacement of a chlorine eductor), the checklist questions (see Chapter 6) that apply to the equipment being changed are likely to be sufficient. Or your supplier could possibly refer you to other WWTPs that use it, and you could check with them to see if any problems have come up that are worth further check or study.

***The objective is to be very sure that after the change has been made, the process or plant is safe to operate before you start to use it.*** Take the time to analyze the change and check the system carefully.

#### WHERE TO GO FOR MORE INFORMATION

- g** *Management of Change in Chemical Plants: Learning from Case Histories*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1993.
- g** *Plant Guidelines for Technical Management of Chemical Process Safety*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1992.
- g** *Management of Process Hazards (RP 750)*, American Petroleum Institute.
- g** *Guidelines for Engineering Design for Process Safety*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1993.

### 7.8 PRE-STARTUP REVIEW (§68.77)

You must conduct your pre-startup safety review for new stationary sources or modified stationary sources when the modification is significant enough to require a change in safety information under the management of change element. You must conduct your pre-startup review before you introduce a regulated substance to a process, and you must address the items listed in Exhibit 7-8.

#### EXHIBIT 7-8 PRE-STARTUP REVIEW REQUIREMENTS

Design Specifications	Adequate Procedures	PHA/MOC	Training
UConfirm that new or modified construction and equipment meet design specifications.	UEnsure that procedures for safety, operating, maintenance, and emergencies are adequate and in place.	Perform a PHA and resolve or implement any recommendations for new process. Meet management of change requirements for modified process.	UConfirm that each employee involved in the process has been trained completely.

Like Management of Change, in the preceding section, this element of the RMP rule is to make sure that changes you intend to make are safe to operate before you put them into operation. It places the responsibility squarely on the operator to check that persons making the change (e.g., the maintenance people, or the engineering firm) have properly completed the job before start up. If it is not properly completed, it is not acceptable to start the process.

If you do not have the expertise to do conduct a pre-startup review, you will need to arrange for someone with the necessary expertise to conduct it. Pre-startup safety review is an intended redundancy to the Management of Change requirements. Again, the principle is take the time to analyze the change and check the system carefully before operating it.

## 7.9 COMPLIANCE AUDITS (§68.79)

You must conduct an audit of the process to evaluate compliance with the prevention program requirements at least once every three years. At least one person involved in the audit must be knowledgeable in the process. You must develop a report of the findings and document appropriate responses to each finding and document that deficiencies have been addressed. The two most recent audit reports must be kept on-site.

The OSHA compliance guideline, CPL 2-2.34a, is a good starting point for an audit of the prevention program for a WWTP. Operators should apply the questions to that portion of their facility that uses or handles the regulated substances present on the plant. It is critical that you resolve any questions raised by, or findings of, the audit. These are likely to describe flaws in the management of process safety that could lead to a release of highly toxic or flammable gases. Continued operation with such flaws should not be permitted.

### WHERE TO GO FOR MORE INFORMATION

- g** *Guidelines for Auditing Process Safety Management Systems*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1993.

## 7.10 INCIDENT INVESTIGATION (§68.81)

Exhibit 7-9 briefly summarizes the steps you must take for investigating incidents.

### EXHIBIT 7-9 INCIDENT INVESTIGATION REQUIREMENTS

<b>U</b> Initiate an investigation promptly.	Begin investigating no later than 48 hours following the incident.
<b>U</b> Establish a knowledgeable investigation team.	Establish an investigation team to gather the facts, analyze the event, and develop the how and why of what went wrong. At least one team member must have knowledge of the process involved. Consider adding other workers in the process area where the incident occurred. Their knowledge will be significant and should give you the fullest insight into the incident.
<b>U</b> Summarize the investigation in a report.	Among other things, the report must identify the factors contributing to the incident. Remember that identifying the root cause may be more important than identifying the initiating event. The report must also include any recommendations for corrective actions. Remember that the purpose of the report is to help management take corrective action.
<b>U</b> Address the team's findings and recommendations.	Establish a system to address promptly and resolve the incident report findings and recommendations; document resolutions and corrective actions.
<b>U</b> Review the report with your staff and contractors.	You must share the report - its findings and recommendations - with affected workers whose job tasks are relevant to the incident.
<b>U</b> Retain the report.	Keep incident investigation reports for five years.

You must investigate each incident which resulted in, or could have resulted in, a "catastrophic release of a regulated substance." A catastrophic release is one that "presents an imminent and substantial endangerment to public health and the environment." Although the rule requires you to investigate only those incidents which resulted in, or could reasonably have resulted in a catastrophic release, EPA encourages you to investigate all accidental releases. Investigating minor accidents or near misses can help you identify problems that could result in major releases if left unaddressed.

#### WHERE TO GO FOR MORE INFORMATION

- g** *Guidelines for Investigating Chemical Process Incidents*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1992.
- g** *Guide for Fire and Explosion Investigations (NFPA 921)*, National Fire Protection Association.

**7.11 EMPLOYEE PARTICIPATION (§68.83)**

Exhibit 7-10 briefly summarizes what you must do.

**EXHIBIT 7-10  
EMPLOYEE PARTICIPATION REQUIREMENTS**

<b>U</b> Write a plan.	Develop a written plan of action regarding how you will implement employee participation.
<b>U</b> Consult with employees.	Consult your employees and their representatives regarding conducting and developing PHAs and other elements of process safety management in the risk management program rule.
<b>U</b> Provide access to information.	Ensure that your employees and their representatives have access to PHAs and all other information required to be developed under the rule.

**7.12 HOT WORK PERMITS (§68.85)**

Exhibit 7-11 briefly summarizes how to meet the hot work permit requirement.

**EXHIBIT 7-11  
HOT WORK PERMITS REQUIREMENTS**

<b>U</b> Issue a hot work permit.	You must issue this permit for hot work conducted on or near a covered process.
<b>U</b> Implement fire prevention and protection.	You must ensure that the fire prevention and protection requirements in 29 CFR 1910.252(a) are implemented before the hot work begins. The permit must document this.
<b>U</b> Indicate the appropriate dates.	The permit should indicate the dates authorized for hot work.
<b>U</b> Identify the work.	The permit must identify the object on which hot work is to be performed.
<b>U</b> Maintain the permit on file.	You must keep the permit on file until workers have completed the hot work operations.

Welding, cutting, brazing, grinding, sandblasting, and other spark-producing work is subject to this element of the standard. Because there is likely to be flammable gas present, you should consider that fire or explosion hazards exist.

The value in hot work procedures comes from the use of permits as a communication device. They are intended to communicate the hazards, and needed precautions, to the workers performing work under the permits. Also, the provision of the permit to operators will inform them of the nature of the work in progress, so that they can

govern their activity so as not to interfere with or provide additional hazard to the job in progress.

#### WHERE TO GO FOR MORE INFORMATION

- g *Standard for Fire Prevention in Use of Cutting and Welding Processes* (NFPA 518), National Fire Protection Association.
- g *Standard for Welding, Cutting and Brazing*, 29 CFR 1910 Subpart Q.

### 7.13 CONTRACTORS (§68.87)

Exhibit 7-12 summarizes both yours and the contractors' responsibilities where contractors perform maintenance or repair, turnaround, major renovation, or specialty work on or adjacent to a covered process.

#### EXHIBIT 7-12 CONTRACTORS CHART

<u>You must...</u>	<u>Your contractor must...</u>
<b>UCheck safety performance.</b> When selecting a contractor, you must obtain and evaluate information regarding the safety performance of the contractor.	<b>UEnsure training for its employees.</b> The contractor must train its employees to ensure that they perform their jobs safely and in accordance with your source's safety procedures.
<b>UProvide safety and hazards information.</b> You must inform the contractor of potential fire, explosion, or toxic release hazards; and of your emergency response activities as they relate to the contractor's work and the process.	<b>UEnsure its employees know process hazards and applicable emergency actions.</b> The contractor must assure that contract employees are aware of hazards and emergency procedures relating to the employees' work.
<b>UEnsure safe practices.</b> You must ensure that you have safe work practices to control the entrance, presence, and exit of contract employees in covered process areas.	<b>UDocument training.</b> The contractor must prepare a record documenting and verifying adequate employee training.
<b>UVerify that the contractor acts responsibly.</b> You must verify that the contractor is fulfilling its responsibilities.	<b>UEnsure its employees are following your safety procedures.</b>
	<b>UInform you of hazards.</b> The contractor must tell you of any unique hazards presented by its work or of any hazards it finds during performance.

#### EPA/OSHA DIFFERENCES

EPA has no authority to require that you maintain an occupational injury and illness log for contract employees. Be aware, however, that OSHA does have this authority, and that the PSM standard does set this requirement. (See 29 CFR 1910.119(h)(2)(vi)).

**WHERE TO GO FOR MORE INFORMATION**

- g**     *Contractor and Client Relations to Assure Process Safety*, Center for Chemical Process Safety of the American Institute of Chemical Engineers 1996.
- g**     *API/CMA Managers Guide to Implementing a Contractor Safety Program* (RP 2221), American Petroleum Institute.
- g**     *Improving Owner and Contractor Safety Performance* (RP 2220), American Petroleum Institute.

## **APPENDIX 7-A PHA TECHNIQUES**

This appendix provides descriptions of each of the PHA techniques listed in the OSHA PSM standard and § 68.67. These descriptions include information on what each technique is, which types of processes they may be appropriate for, what their limitations are, and what level of effort is typically associated with each. This information is based on *Guidelines for Hazard Evaluation Procedures*, 2nd Ed., published by AIChE/CCPS. If you are interested in more detailed discussion and worked examples, you should refer to the AIChE/CCPS volume.

Neither the information below nor the full AIChE/CCPS volume will provide you with enough information to conduct a PHA. The rule requires that your PHA team include at least one person trained in the technique you use. Training in PHA techniques is available from a number of organizations. If you must conduct multiple PHAs, you are likely to need to update your PHAs frequently, or you have a complex process that will take several weeks to analyze, you may want to consider training one or more of your employees. If you have a single process that is unlikely to change more than once every five years, you may find it more cost-effective to hire a trained PHA leader.

### **DESCRIPTIONS OF TECHNIQUES**

#### **CHECKLISTS**

Checklists are primarily used for processes that are covered by standards, codes, and industry practices — for example, storage tanks designed to ASME standards or ammonia handling covered by OSHA (29 CFR 1910.111).. Checklists are easy to use and can help familiarize new staff with the process equipment. AIChE/CCPS states that checklists are a highly cost-effective way to identify customarily recognized hazards. Checklists are dependent on the experience of the people who develop them; if the checklist is not complete, the analysis may not identify hazardous situations.

Checklists are created by taking the applicable standards and practices and using them to generate a list of questions that seek to identify any differences or deficiencies. If a checklist for a process does not exist, an experienced person must develop one based on standards, practices, and facility or equipment experience. A completed checklist usually provides "yes," "no," "not applicable," and "need more information" answers to each item. A checklist analysis involves touring the process area and comparing equipment to the list.

AIChE/CCPS estimates that for a small or simple system a checklist will take 2 to 4 hours to prepare, 4 to 8 hours to evaluate the process, and 4 to 8 hours to document the results. For larger or more complex processes, a checklist will take 1 to 3 days to prepare, 3 to 5 days to evaluate, and 2 to 4 days to document.

Examples of checklists are given in Chapter 6, Appendix 6-A.



## WHAT-IF

A What-If is a brainstorming approach in which a group of people familiar with the process ask questions about possible deviations or failures. These questions may be framed as What-If, as in "What if the pump fails?" or may be expressions of more general concern, as in "I worry about contamination during unloading." A scribe or recorder takes down all of the questions on flip charts or a computer. The questions are then divided into specific areas of investigation, usually related to consequences of interest. Each area is then addressed by one or more team members.

What-If analyses are intended to identify hazards, hazardous situations, or accident scenarios. The team of experienced people identifies accident scenarios, consequences, and existing safeguards, then suggest possible risk reduction alternatives. The method can be used to examine deviations from design, construction, modification, or operating intent. It requires a basic understanding of the process and an ability to combine possible deviations from design intent with outcomes. AIChE describes this as a powerful procedure if the staff are experienced; "otherwise, the results are likely to be incomplete."

A What-If usually reviews the entire process, from the introduction of the chemicals to the end. The analysis may focus on particular consequences of concern. AIChE provides the following example of a What-If question: "What if the raw material is the wrong concentration?" The team would then try to determine how the process would respond: "If the concentration of acid were doubled, the reaction could not be controlled and a rapid exotherm would result." The team might then recommend steps to prevent feeding wrong concentrations or to stop the feed if the reaction could not be controlled.

A What-If of simple systems can be done by one or two people; a more complex process requires a larger team and longer meetings. AIChE/CCPS estimates that for a small or simple system a What-If analysis will take 4 to 8 hours to prepare, 1 to 3 days to evaluate the process, and 1 to 2 days to document the results. For larger or more complex processes, a What-If will take 1 to 3 days to prepare, 4 to 7 days to evaluate, and 4 to 7 days to document.

Examples of What If questions are given in Chapter 6, Appendix 6-A.

## WHAT-IF/CHECKLIST

A What-If/Checklist combines the creative, brainstorming aspects of the What-If with the systematic approach of the Checklist. The combination of techniques can compensate for the weaknesses of each. The What-If part of the process can help the team identify hazards and accident scenarios that are beyond the experience of the team members. The checklist provides a more detailed systematic approach that can fill in gaps in the brainstorming process. The technique is generally used to identify the most common hazards that exist in a process. AIChE states that it is often the first PHA conducted on a process, with subsequent analyses using more detailed approaches.

The purpose of a What-If/Checklist is to identify hazards and the general types of accidents that could occur, evaluate qualitatively the effects of the effects, and determine whether safeguards are adequate. Usually the What-If brainstorming precedes the use of the checklist, although the order can be reversed.

The technique usually is performed by a team experienced in the design, operation, and maintenance of the process. The number of people required depends on the complexity of the process.

AICHE/CCPS estimates that for a small or simple system a What-If/Checklist analysis will take 6 to 12 hours to prepare, 6 to 12 hours to evaluate the process, and 4 to 8 hours to document the results. For larger or more complex processes, a What-If/Checklist will take 1 to 3 days to prepare, 4 to 7 days to evaluate, and 1 to 3 weeks to document.

See Chapter 6 for a further discussion of What If/Checklists.

## **HAZOP**

The Hazard and Operability Analysis (HAZOP) was originally developed to identify both hazards and operability problems at chemical process plants, particularly for processes using technologies with which the plant was not familiar. The technique has been found to be useful for existing processes as well. A HAZOP requires an interdisciplinary team and an experienced team leader.

The purpose of a HAZOP is to review a process or operation systematically to identify whether process deviations could lead to undesirable consequences. AICHE states that the technique can be used for continuous or batch processes and can be adapted to evaluate written procedures. It can be used at any stage in the life of a process.

HAZOPs usually require a series of meetings in which, using process drawings, the team systematically evaluates the impact of deviations. The team leader uses a fixed set of guide words and applies them to process parameters at each point in the process. Guide words include "No," "More," "Less," "Part of," "As well as," "Reverse," and "Other than." Process parameters considered include flow, pressure, temperature, level, composition, pH, frequency, and voltage. As the team applies the guide words to each process step, they record the deviation, with its causes, consequences, safeguards, and actions needed, or the need for more information to evaluate the deviation.

HAZOPs require more resources than simpler techniques. AICHE states that a simple process or a review with a narrow scope may be done by as few as three or four people, if they have the technical skills and experience. A large or complex process usually requires a team of five to seven people. AICHE/CCPS estimates that for a small or simple system a HAZOP analysis will take 8 to 12 hours to prepare, 1 to 3 days to evaluate the process, and 2 to 6 days to document the results. For larger or more complex processes, a HAZOP will take 2 to 4 days to prepare, 1 to 3 weeks to evaluate, and 2 to 6 weeks to document.

See Chapter 6 for a further discussion of HAZOPs.

## **FAILURE MODE AND EFFECTS ANALYSIS (FMEA)**

A Failure Mode and Effects Analysis (FMEA) evaluates the ways in which equipment fails and the system's response to the failure. The focus of the FMEA is on single equipment failures and system failures. An FMEA usually generates recommendations for increasing equipment reliability. FMEA does not examine human errors directly, but will consider the impact on equipment of human error. AICHE states that FMEA is "not efficient for identifying an exhaustive list of combinations of equipment failures that lead to accidents."

An FMEA produces a qualitative, systematic list of equipment, failure modes, and effects. The analysis can easily be updated for design or systems changes. The FMEA usually produces a table that,

for each item of equipment, includes a description, a list of failure modes, the effects of each failure, safeguards that exist, and actions recommended to address the failure. For example, for pump operating normal, the failure modes would include fails to stop when required, stops when required to run, seal leaks or ruptures, and pump case leaks or ruptures. The effects would detail both the immediate effect and the impact on other equipment. Generally, when analyzing impacts, analysts assume that existing safeguards do not work.

An FMEA requires an equipment list or P&ID, knowledge of the equipment, knowledge of the system, and responses to equipment failure. AIChE states that on average, an hour is sufficient to analyze two to four pieces of equipment. AIChE/CCPS estimates that for a small or simple system an FMEA will take 2 to 6 hours to prepare, 1 to 3 days to evaluate the process, and 1 to 3 days to document the results. For larger or more complex processes, an FMEA will take 1 to 3 days to prepare, 1 to 3 weeks to evaluate, and 2 to 4 weeks to document.

### **FAULT TREE ANALYSIS (FTA)**

A Fault Tree Analysis (FTA) is a deductive technique that focuses on a particular accident or main system failure and provides a method for determining causes of the event. The fault tree is a graphic that displays the combinations of equipment failures and human errors that can result in the accident. The FTA starts with the accident and identifies the immediate causes. Each immediate cause is examined to determine its causes until the basic causes of each are identified. AIChE states that the strength of FTA is its ability to identify combinations of basic equipment and human failures that can lead to an accident, allowing the analyst to focus preventive measures on significant basic causes.

AIChE states that FTA is well suited for analyses of highly redundant systems. For systems vulnerable to single failures that can lead to accidents, FMEA or HAZOP are better techniques to use. FTA is often used when another technique has identified an accident that requires more detailed analysis. The FTA looks at component failures (malfunctions that require that the component be repaired) and faults (malfunctions that will remedy themselves once the conditions change). Failures and faults are divided into three groups: primary failures and faults occur when the equipment is operating in the environment for which it was intended; secondary failures and faults occur when the system is operating outside of intended environment; and command faults and failures are malfunctions where the equipment performed as designed but the system that commanded it malfunctioned.

An FTA requires a detailed knowledge of how the plant or system works, detailed process drawings and procedures, and knowledge of component failure modes and effects. AIChE states that FTAs need well trained and experienced analysts. Although a single analyst can develop a fault tree, input and review from others is needed.

AIChE/CCPS estimates that for a small or simple system an FTA will take 1 to 3 days to prepare, 3 to 6 days for model construction, 2 to 4 days to evaluate the process, and 3 to 5 days to document the results. For larger or more complex processes, an FTA will take 4 to 6 days to prepare, 2 to 3 weeks for model constructions, 1 to 4 weeks to evaluate, and 3 to 5 weeks to document.

### **Other Techniques**

The rule allows you to use other techniques if they are functionally equivalent. The AIChE Guidelines includes descriptions of a number of other techniques including Preliminary Hazard Review,

Cause-Consequence Analysis, Event Tree Analysis, and Human Reliability Analysis. You may also develop a hybrid technique that combines features of several techniques or apply more than one technique.

## Selecting a Technique

Exhibit 7A-1 is adapted from the AIChE Guidelines and indicates which techniques are appropriate for particular phases in a process's design and operation.

**EXHIBIT 7A-1**  
**APPLICABILITY OF PHA TECHNIQUES**

	Checklist	What-If	What-If- Checklist	HAZOP	FMEA	FTA
R&D		T				
Design	T	T	T			
Pilot Plant Operation	T	T	T	T	T	T
Detailed Engineering	T	T	T	T	T	T
Construction/Start-Up	T	T	T			
Routine Operation	T	T	T	T	T	T
Modification	T	T	T	T	T	T
Incident Investigation		T		T	T	T
Decommissioning	T	T	T			

## Factors in Selecting a Technique

Type of process will affect your selection of a technique. AIChE states that most of the techniques can be used for any process, but some are better suited for certain processes than others. FMEA efficiently analyzes the hazards associated with computer and electronic systems; HAZOPs do not work as well with these. Processes or storage units designed to industry or government standards can be handled with checklists.

Analysis of multiple failure situations is best handled by FTA. Single-failure techniques, such as HAZOP and FMEA, are not normally used to handle these although they can be extended to evaluate a few simple accident situations involving more than one event.

AIChE states that when a process has operated relatively free of accidents for a long time, the potential for high consequence events is low, and there have been few changes to invalidate the experience base, the less exhaustive techniques, such as a Checklist, can be used. When the opposite is true, the more rigorous techniques are more appropriate.

A final factor in selecting a technique is time required for various techniques. Exhibit 7A-2 summarizes AIChE's estimates of the time required for various steps. The full team is usually involved in the evaluation step; for some techniques, only the team leader and scribe are involved in the preparation and documentation steps.

**EXHIBIT 7A-2**  
**TIME AND STAFFING FOR PHA TECHNIQUES**

	Checklist	What-If	What-If Checklist	HAZOP	FMEA	FTA
<b>Simple/Small System</b>						
# Staff	1-2	2-3	2-3	3-4	1-2	2-3
Preparation	2-4 h	4-8 h	6-12 h	8-12 h	2-6 h	1-3 d
Modeling						3-6 d
Evaluation	4-8 h	1-3 d	6-12 h	1-3 d	1-3 d	2-4 d
Documentation	4-8 h	1-2 d	4-8 h	2-6 d	1-3 d	3-5 d
<b>Large/Complex Process</b>						
# Staff	1-2	3-5	3-5	5-7	2-4	2-5
Preparation	1-3 d	1-3 d	1-3 d	2-4 d	1-3 d	4-6 d
Modeling						2-3 w
Evaluation	3-5 d	4-7 d	4-7 d	1-3 w	1-3 w	1-4 w
Documentation	2-4 d	4-7 d	1-3 w	2-6 w	2-4 w	3-5 w

h = hours      d = days (8 hours)      w = weeks (40 hours)

